NATIVE FISHES IN HANALEI RIVER, KAUAI, AND THE POTENTIAL IMPACT OF HYDROELECTRIC DEVELOPMENT: A PRELIMINARY STUDY

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ABSTRACT

Hanalei River is among the top ten pristine streams in the State (Timbol 1977). Seven fish species reside in the river. Five are endemic. One endemic is considered depleted on other islands (Miller 1972), except on Kauai where it supports a seasonal fishery jointly exploited by commercial and recreational fishermen. A hydroelectric facility is proposed to be built which will affect the habitat of these endemics. Potential adverse impacts include blockage of diadromous fish migration, dewatering of about 6 km of mainstream out of a total of 18 km, and mortality of fish, eggs and larvae related to the operation of the hydroelectric facility. Mitigative measures suggested are continuous water flow over the diversion weir, installing a "fish chute" and fish screen, minimum instream flow of 36 cfs, avoiding plant operation during peak fish migration, and replacing fish stocks with hatchery reared fish.

INTRODUCTION

The native Hawaiian freshwater fishes are unique, having evolved on small, geographically isolated land masses. There are only five freshwater native fishes, four of which are endemic. Apart from their socio-economic values, these endemics have intrinsic biological values (Parrish *et al*. 1978). Any resource development plans that may impact their limited, insular freshwater habitat must be considered carefully, including cumulative impacts.

Hanalei River on the island of Kauai is one of the most pristine streams in the State based on faunal inventory, species composition and diversity (Timbol 1977). There is now a proposal to divert water from the Hanalei River in order to generate electricity. Our purpose is threefold. First, to gather, interpret, and integrate existing biological data on the distribution and relative abundances of fishes in the Hanalei River. Second, to determine the possible impacts that the construction and operation of the hydroelectric facility will have on the native fishes. Third, to suggest mitigative measures to ensure the survival of these economically and biologically important fishes in the Hanalei River.

Previous work on Hanalei River involved the ecology of aquatic macrofauna (Timbol 1977), and an environmental impact assessment for the Hanalei National Wildlife Refuge located adjacent to the lower reaches of the stream (Wilson Okamoto and Associates 1979). A related study dealt with food sources of endangered waterbirds in the Hanalei National Wildlife Refuge (Broshears and Moriarty 1979).

The opinions, findings, conclusions, or recommendations in this paper are those of the authors and do not necessarily reflect those of the Kauai Community College or the Department of Land and Natural Resources.

Physiography and Climate

Hanalei Valley is located on Kauai's north shore. It is long, relatively narrow, and extends from the sea to Mount Waialeale. For the first 13 km the valley floor ascends to an elevation of only 180 m. In the remaining 5 km, the valley floor rises to 1,500 m. Its width varies from 3 to 5 km. The drainage area is about 60 km^2.

Annual rainfall varies from about 200 cm near the coastline to about 1,000 cm at the head of the valley (Taliaferro 1959). The average monthly air remperature is in the lower 20's (°C). The average wind velocity is about 11 km/h and blows predominantly from the east (Ramage and Oshiro 1977).

Hanalei River and Location of Proposed Facility

Long term flow rate for Hanalei River average 227 cfs. In 1975, flows varied from 24 cfs to 21,600 cfs. According to USGS records, flows in excess of 36 cfs occur 99.2% of the time (USGS 1976).

The proposed hydropower facility is shown in Fig. 1. The location of the diversion weir, penstock, and powerplant in relation to the stream channel and drainage basin are shown in this figure. Surface flow will be diverted at 195 m elevation, conveyed through a penstock (pipe) for about 6 km and released downstream as tailwater after passing through turbines in the powerhouse located at about 35 m elevation.

MATERIALS AND METHODS

Data used in this paper were collected in 1977 and 1982. The 1977 data (Timbol 1977) were obtained by electroshocking and the 1982 data by underwater visual observations (Heacock, unpublished). The effectiveness of electroshocking on warmwater fishes is discussed by Larimore (1966), and in insular streams by Maciolek and Timbol (1980). Advantages of fish observations using snorkel gear over electroshocking are discussed by several authors (Northcote and Wilkie 1963, Goldstein 1978, and Zalewski 1985). Also, potential sources of bias using electroshocking to sample fish are discussed by Maciolek and Timbol (1980), while those for snorkeling methods are discussed by Griffith and Schill (in press).

The resulting list of fishes observed in the Hanalei River was checked for endangered and threatened species using the following publication list: Deacon et al. (1979), USFWS List of Endangered and Threatened Species (1977), and Miller (1972).

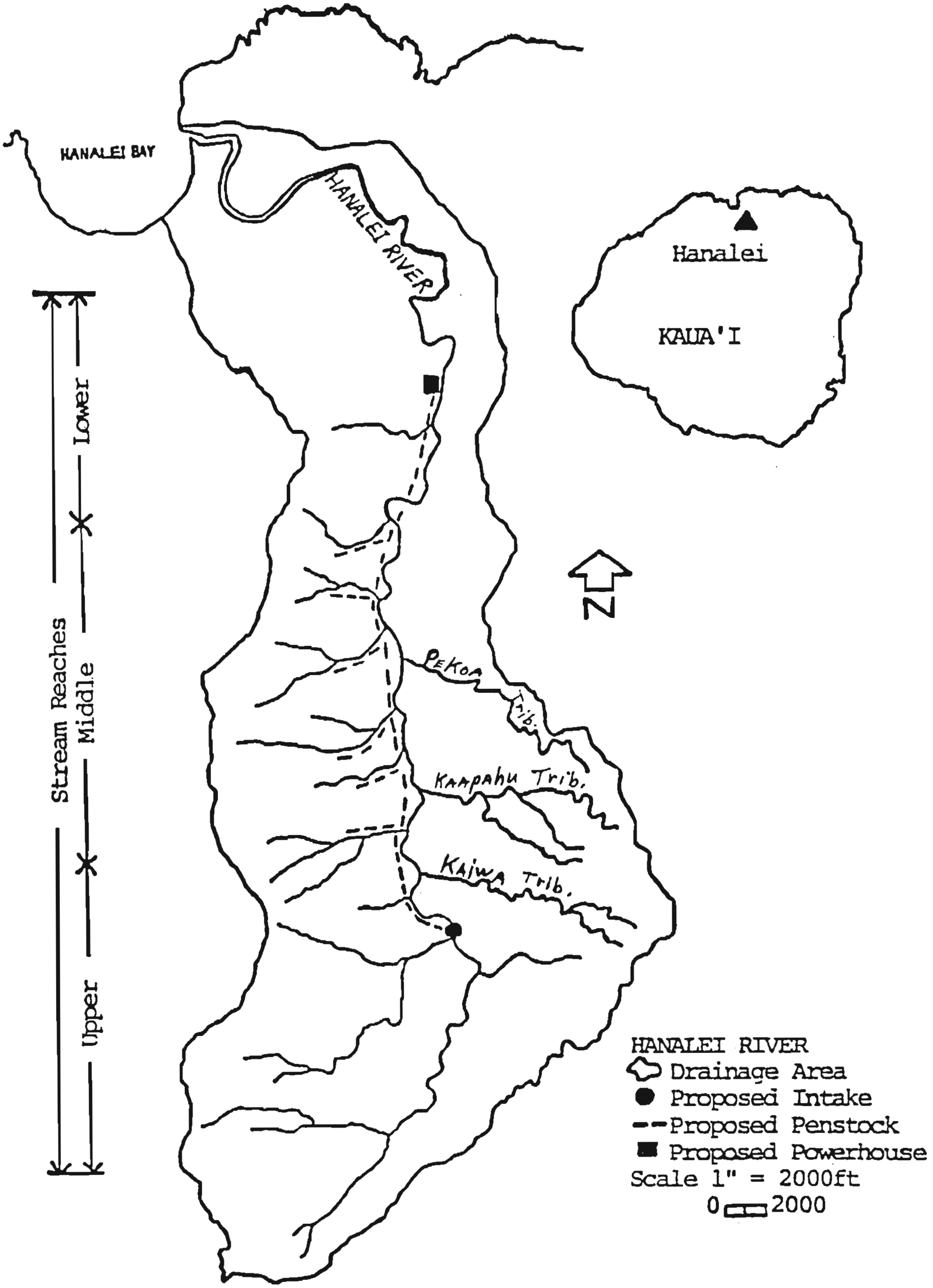


FIGURE 1. Map of Hanalei River, Kaua'i, showing proposed hydropower facility.

Terms used in the text are: depleted, which means that the organisms are still found in numbers adequate for survival but have been heavily depleted and continues to decline substantially (Miller 1972); rare are those not under immediate threat of extinction but occur in small numbers; endangered are those that are actively threatened with extinction; and threatened species include those which are depleted, rare, or endangered. Additional terms needing clarification are: endemic, which means occuring naturally in Hawaii only; indigenous means occurring naturally in Hawaii and elsewhere; native includes both indigenous and endemic; and alien means that the animal was brought to Hawaii either accidentally or intentionally.

For purposes of this report, abundant (+++) means many individuals, from 6 to 20 or more, were observed per 20 m^2 (standard) sampling area. Common (++) indicates that between 2 and 5 were observed or caught, while uncommon (+) means that only one was sighted or caught, and absent (0) means it was neither seen nor collected.

Distribution and Relative Abundances

Data collected five years apart show seven fish species: 3 are endemic, 2 indigenous, and 2 alien (Table 1). The most important component of the fish community is the 'o'opu-nakea (*Awaous stamineus*) which is listed as threatened (Deacon *et al*. 1979, Miller 1972). A decline in its population density is a good indication of serious stream degradation.

The 'o'opu-nakea is the largest (up to 35 cm) of the freshwater gobies and it is found in all stream reaches, from sea level to the head waters at 500 m elevation. The life history of this endemic goby has been studied by Ego (1956) and is illustrated in Fig. 2. During their spawning season (August through December) 'o'opu-nakea migrate downstream and deposit their eggs on stones in the lower reaches of the stream. The eggs hatch in 24 hours and the larvae are carried out to sea by water currents. The larvae spend between 4 and 7 months in the ocean as part of the zooplankton. They return to streams as transparent fry (postlarvae) and start upstream migration to their places of permanent residence where they attain sexual maturity in a year. The 'o'opu-nakea is an obligately diadromous animal and needs suitable environmental conditions throughout the stream channel to enable both its larvae to drift downstream to reach the sea, and its postlarvae to migrate upstream. On Kauai, the 'o'opu-nakea supports a seasonal (April through December), joint recreational and commercial fishery.

Two other native gobies are found in Hanalei River: the indigenous 'o'opu-naniha (*Awaous genivitatus*) and the endemic 'o'opu-nopili (*Sicyopterus stimpsoni*). The former is small (up to 15 cm) and characterized by a broad, slanting blotch extending from below the eye downward and backward across the cheek. It lives primarily in brackish water in the lower reaches of the river, but has been observed 1.5 km above the estuary. The 'o'opu-nopili grows to 18 cm, is found in all stream areas, but mostly in the lower reaches. 'O'opu-nopili females can produce several thousand eggs (Tomihama 1972). The larvae are swept to sea, become planktonic, then metamorphose into postlarvae at stream mouths and begin their upstream migrations; a life cycle essentially the same as that of the 'o'opu-nakea. The

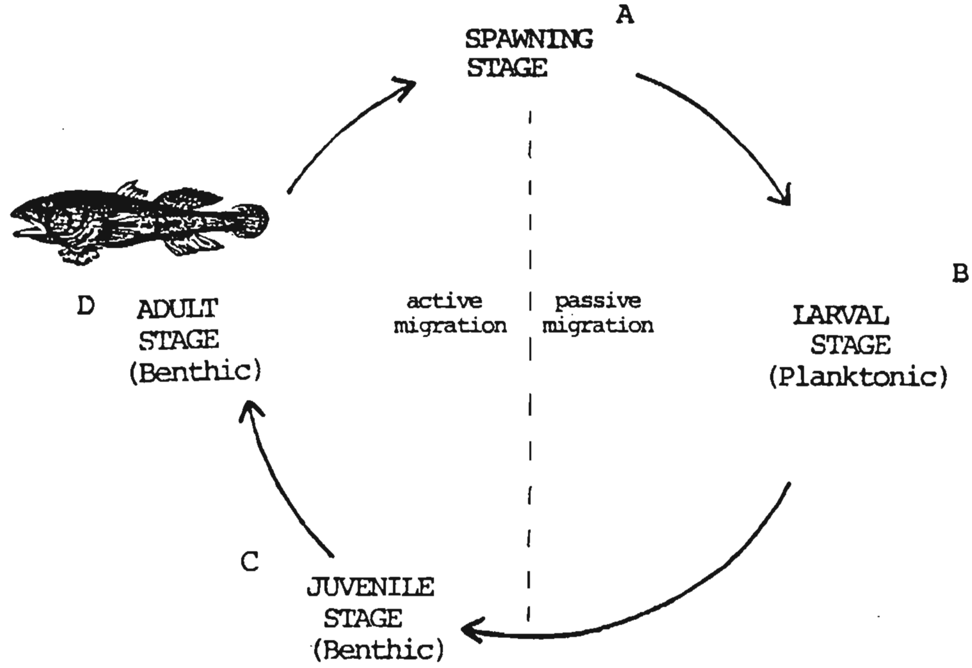
TABLE 1. Fishes in the Hanalei River, Kauai.

Scientific Name	Local Name	Origin	Listing[1]
1. *Awaous stamineus*	'o'opu-nakea	endemic	depleted on Oahu[2], special concern[3]
2. *Awaous genivittatus*	'o'opu-naniha	indigenous	none
3. *Sicyopterus stimpsoni*	'o'opu-nopili	endemic	none
4. *Eleotris sandwicensis*	'o'opu-akupa	endemic	none
5. *Kuhlia sandvicensis*	aholehole	endemic	none
6. *Sarotherodon mossambicus*	tilapia	alien	none
7. *Xiphophorus helleri*	swordtail	alien	none

[1] Considered as endangered or threatened in official register or scientific publication.

[2] Depleted means the species still occurs in low numbers but continues to decline at a rate substantially greater than can be sustained (Miller 1972).

[3] Deacon *et al.* (1979).



A - Spawning takes place on rocks in estuaries during the months of August through November. Eggs are laid on rocks and guarded by the adults. Eggs hatch in about 24 hrs and larvae are passively swept to sea (Ego 1956).

B - Larvae (hinana) are translucent, surface-swimming, and are passively transported inter-island and inter-stream by ocean currents. The larval stage lasts about 4 to 6 months (Ego _op cit_.).

C - Juvenile fish are benthic and actively migrate upstream with the aid of their fused pelvic fins which function as a ventral,suctorial organ.

D - Adults actively migrate downstream during the months of August through November, assisted by heavy freshets, and spawn on rock substrate in the estuarine portion, or extreme lower reaches, of the stream.

FIGURE 2. Life history of 'o'opu nakea, _Awaous stamineus_.

'o'opu-nopili, because it requires clean fresh water flowing in considerable volume through a comparatively unaltered stream channel, and since it is not subject to harvesting (as is the 'o'opu-nakea), has been suggested by Timbol and Maciolek (1978) as an indicator species for a pristine stream.

The absence of certain animals in a particular habitat, such as Hanalei River, could be as ecologically significant as their presence. Absent in Hanalei River was the endemic goby, 'o'opu-alamo'o (Lentipes concolor), a threatened species (Deacon et al. 1979). This river does not appear to be characteristic habitat of 'o'opu-alamo'o (Maciolek 1978, Kinzie and Ford 1982).

Table 2 compares the relative abundances of the seven fish residents. There was no species decline or increase from 1977 through 1982. Two species ('o'opu-nakea and 'o'opu-nopili) are found in all reaches of the stream. They, however, are more abundant (+++) in the lower reaches. Their population densities decline with elevation: common (++) in the middle reaches and uncommon (+) in the upper reaches.

The 'o'opu-naniha and 'o'opu-okuhe (Eleotris sandwicensis) are found primarily in the lower reaches, but also extend into the middle reaches of the river (see Fig. 1). The distributional pattern of these two species is a function of the river basin topography. The river profile is gently sloping for the first 13 km. However, in the remaining 5 km the valley floor climbs rapidly (Wilson Okamoto and Associates 1979). Thus, even the 'o'opu-okuhe, which lack the fused, suctorial pelvic fins of gobiid fishes, and the 'o'opu-naniha, a goby which prefers slow flowing water, are able to inhabit the middle reaches of Hanalei River.

The tilapia (Sarotherodon mossambicus), an alien species, fortunately is still found only in the lower reaches of the stream. Tilapia are believed to be important competitors with, and possibly predators of, the native stream biota (Maciolek 1984). Additionally, the live-bearing swordtail (Xiphophorus helleri) is found in both lower and middle reaches.

There appear to be no significant differences between the relative abundances in 1977 and 1982 (Table 2). However, the apparent difference in the abundances of 'o'opu-okuhe and tilapia (rows 4 and 5) is a function of data collection methods used in 1977 (electroshocking) and 1982 (snorkeling, see Materials and Methods) and behavior of these fishes. The 'o'opu-okuhe are cryptic and hide under boulders and other materials when disturbed. As a result, direct underwater observations using snorkel gear tend to underestimate the abundance of this species. Similar observations regarding cryptic species have been made in U.S. mainland streams (Platt, Megahan and Minshall 1983). In contrast, 'o'opu-okuhe is extremely susceptible to electroshocking (Maciolek and Timbol 1980). Therefore, it is not surprising that 'o'opu-okuhe abundance was underestimated in the data collected in 1982.

The tilapia, on the other hand, is an ideal fish to estimate by visual methods because it holds its territory even in the presence of an underwater observer. In contrast, the effect of electroshocking on tilapia range from disturbance to only some immobilization (Maciolek and Timbol 1980). Thus, tilapia are likely to be underestimated in the electroshocking data (lower, 1977 column).

TABLE 2. Relative abundances of fishes in Hanalei River, Kaua'i.

Stream Reaches: (elevation in meters)	Upper (365-427m)		Middle (122-183m)		Lower (6-60m)	
	1977[1]	1982[2]	1977[1]	1982[2]	1977[1]	1982[2]
1. *Awaous stamineus*	+	(x)	++	(+++)	+++	(+++)
2. *Awaous genivittatus*	0	(x)	0	(+)	++	(++)
3. *Sicyopterus stimpsoni*	+	(x)	+	(++)	++	+
4. *Eleotris sandwicensis*	0	(x)	0	(+)	+++	(+)
5. *Kuhlia sandvicensis*	0	(x)	0	(0)	++	(++)
6. *Sarotherodon mossambicus*	0	(x)	0	(0)	+	(+++)
7. *Xiphophorus helleri*	0	(x)	+++	(+++)	+++	(+++)

[1] Samples collected by electroshocking methods, July-August, 1977 (Timbol and Environmental Impact Studies Corp. 1977).

[2] Sampling done by underwater observations (i.e. snorkeling methods), June 1982, (Heacock unpubl.).

Legend: (x) = no data available
0 = absent
\+ = uncommon
++ = common
+++ = abundant

Potential Adverse Impacts and Mitigative Measures

The potential adverse impacts of hydropower development on fishery resources on the U.S. mainland have been studied by Rochester, Lloyd and Farr (1984) and Boreman (1977). No definitive studies have been done to access the potential impacts hydroelectric facilities may have, or are having, on the Hawaiian stream biota. Timbol (1977, 1983) and USFWS (1978) have done short term studies.

There are at least three major concerns relative to the proposed hydropower facility in Hanalei River. These are: 1) the potential blockage of diadromous fish migration, 2) reduction of instream flow due to water diversion, and 3) mortality of fish passing through penstock and turbines.

In order to divert water to power the turbines, a diversion weir will be built across the river. The weir may form a physical barrier to both upstream migration of the juvenile gobies and the downstream migration of the spawning adults (e.g. 'o'opu-nakea, <u>Awaous stamineus</u>). Although no definitive studies have been made on the effects of such weirs on the 'o'opu-nakea, similar installations have reduced or eliminated anadromous fish populations in many drainage basins elsewhere (Baxter 1977).

Mitigative measures to ensure upstream and downstream fish migration include that ample water be left flowing over the weir at all times (e.g. 12 cfs according to Wilson Okamoto and Associates 1979). To compliment this "ample flow", a "fish chute" should be designed into the downstream face of the weir to facilitate upstream movement of these benthic fishes. Okamoto and Associates (1979) recommended that a fish chute should have a 1:4 slope and be covered with river rocks. Other fish-passage structures have been suggested in order to facilitate fish migration around weirs (Cramer and Oligher 1964, Boreman 1977, Ruggles 1980, Gloss and Wahl 1983).

The diversion of water will reduce instream flow in about 6 km of the channel between the intake upstream and the release downstream. Surface water flow in this dewatered section will be limited to the amount supplied by seepage, ground water and tributary streams (e.g. Kaiwa Stream, Pekoa Stream). This reduction in flow could result in sediment accumulation, stagnant pools, and elevated water temperatures. There will also be the loss of aquatic habitat, and a possible decrease in the carrying capacity of the stream.

Mitigative measures include ensuring enough instream flow to protect the diadromous fishes. This flow should be no less than the natural mean low flow of the river which, according to the USGS (1976), is 36 cfs. Studies on minimum instream flow requirements of native Hawaiian gobies are now underway (Kinzie <u>et</u> <u>al</u>.1984).

The effects of entrainment in penstocks on Hawaiian native fishes have not been studied, although hydroelectric facilities in Hawaiian streams have been in place for some time (e.g. Wainiha River Hydroelectric facility was built in 1906). In a study of fingerling salmon, the U.S. Army Corps of Engineers (1960) found that if the penstock contains air and the fingerlings become acclimated to increased pressure, they may be killed during rapid decompression. Mitigative measures include keeping the fish out of the penstock with the use of fish screens, wing-deflectors, and other structures (Boreman 1977) in order to minimize entrainment by ensuring fish passage around the weir.

In addition to high pressures in the penstock, entrained fish are killed instantaneously as they hit turbine blades or sustain injuries which result in delayed mortality (Rochester, Lloyd and Farr 1984). Delayed mortality is related to stress, physiological deterioration and increased predation. Eggs and early larval stages of fish and other aquatic organisms are particularly vulnerable to entrainment (Boreman 1977).

In order to minimize turbine-induced fish mortality, intake structure design and location must allow for the downstream passage of fish without entrainment into the weir (Boreman 1977). Also, plant operation should be avoided during peak fish migrations.

Finally, fish stocks lost due to the development of hydroelectric facilities can be replaced by hatchery-reared fish (Rochester, Lloyd and Farr 1984). The aquaculture and release of 'o'opu-nakea into streams has great potential as a mitigative measure. Funds should be appropriated to help develop aquaculture techniques for 'o'opu nakea.

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